UNIVERSITI PUTRA MALAYSIA

SPATIAL VARIABILITY OF SOIL FACTORS AFFECTING IRRIGATED LOWLAND RICE YIELD

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FP 2002 38

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Agricultural Science

December 2002

Dedicated to

My beloved mother, wife and children

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Agricultural Science

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December 2002

Chairman: **Anuar Abdul Rahim, Ph.D.**
Faculty: **Agriculture**

Spatial variability of soil chemical and physical properties, and its influence on leaf nutrient content, and yield components were studied in a 0.95 ha rice field in Kuala Selangor. A total of 120 soil samples at 15 cm depth and 120 samples of rice plant were taken at harvesting stage based on grid point sampling of 10m x 10m.

The studies revealed that coefficients of variation for soil physical properties were in the order of bulk density > soil moisture > clay content. Soil chemical properties showed coefficients of variation in the order of K > Mg >total-N > CN ratio > P > Ca > total-S > total-C and Cu > Zn > Na > Mn > pH. The coefficients of variation for leaf nutrient content were found to be in the sequence of Cu > Zn > P > K > Mg > N > Na > Mn > Ca. The range for soil physical properties was found to be in the order of bulk density (134 m) > soil moisture (100 m) > clay content (17 m), while the range for soil chemical properties was in the sequence of Mg (218 m) > total-C (161m) > pH (134 m) ≥ total-S (134 m) ≥ P (134 m) > Ca (120 m) > total-N (54 m) > CN ratio (46 m) > Na (41 m) > Mn (35 m) > Cu (20 m) > Zn (15 m).

Correlation analysis for soil physical properties with yield showed only soil moisture had positive association with yield, while soil chemical properties with yield showed soil total-N, total-C, CN ratio, K, Mn, and Na were significantly associated with yield. There were negative associations between soil total-N with leaf N, soil Ca with leaf Ca, and soil Mn with leaf Mn. Positive associations existed between yield with number of tillers m^{-2}, number of panicles m^{-2}, number of spikelets $panicle^{-1}$, and yield with percentage of filled spikelets. Soil total-N showed positive association with number of panicles m^{-2}, number of spikelets $panicle^{-1}$ and percentage of filled spikelets. Principal component analysis showed the first three principal components accounted for 59% of the total variance and were represented as the fertility status of the soil, substitution cation between Na and K, and bulk density with clay content relationship, respectively. Multiple linear regression analysis for soil properties revealed the equation Yield = 517.78 + 69.13 soil total-N. The equation for leaf nutrient content at rice crop maturity stage was Yield = 524.17 – 256.64 leaf N + 102085.39 leaf Cu + 2663.92 leaf Mn, and equation for yield components was Yield = 1.55 (number of panicles m^{-2}) + 10.20 (number of spikelets $panicle^{-1}$) + 8.05 (percentage of filled spikelets) – 47.61 (seed weight).

Semivariograms and kriging were able to explain the soil and crop attributes variability of the rice field. Kriged map of soil total-nitrogen had the same pattern as kriged map of number of panicles m^{-2}. Geographic information system was able to spatially locate, and calculate the area of a given variable range of values to help in managing the rice field efficiently.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains Pertanian

VARIASI RUANG CIRI-CIRI TANAH YANG MEMPENGARUHI HASIL SAWAH PADI BERPENGAIRAN

Oleh

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Variasi ruang ciri-ciri kimia dan fizik tanah, dan kesannya ke atas kandungan nutrien daun, dan komponen hasil telah dikaji di sawah padi berkeluasan 0.95 ha yang terletak di Kuala Selangor. Sebanyak 120 sampel tanah pada kedalaman 15 cm dan sebanyak 120 sampel bahagian pokok padi telah diambil pada peringkat tuian padi secara penyampelan grid pada jarak 10m x 10m.

Kajian ini menukilkan bahawa pekali variasi ciri fizik tanah mengikut turutan ketumpatan pukal tanah > kelembapan tanah > kandungan lempung. Pekali variasi ciri kimia tanah mengikut turutan K > Mg >jumlah-N > nisbah CN > P > Ca > jumlah-S > jumlah-C dan Cu > Zn > Na > Mn > pH. Pekali variasi untuk kandungan nutrien daun pula mengikut turutan Cu > Zn > P > K > Mg > N > Na > Mn > Ca. Jarak pergantungan ruang sampel untuk ciri fizik tanah didapati mengikut turutan ketumpatan pukal tanah (134 m) > kelembapan tanah (100 m) > kandungan lempung (17 m). Jarak pergantungan ruang sampel untuk ciri kimia tanah pula mengikut turutan Mg (218 m) > jumlah-C (161m) > pH (134 m) ≥ jumlah-S (134 m) ≥ P (134 m) > Ca (120 m) > jumlah-N (54 m) > nisbah CN (46 m) > Na (41 m) > Mn (35 m) > Cu (20 m) > Zn (15 m).

Analisis korelasi ciri fizik tanah menunjukkan perkaitan terus di antara hasil dengan kelembapan tanah. Ciri kimia tanah menunjukkan perkaitan terus di antara hasil dengan jumlah-N dan jumlah-C. Terdapat perkaitan songsang di antara hasil dengan nisbah CN, K, Mn dan Na. Wujud perkaitan songsang di antara jumlah-N tanah dengan N daun, Ca tanah dengan Ca daun, dan Mn tanah dengan Mn daun. Terdapat perkaitan terus di antara hasil dengan bilangan bilah padi m^{-2}, bilangan tangkai m^{-2}, bilangan spikelet $tangkai^{-1}$, dan peratusan spikelet berisi. Wujud perkaitan terus di antara jumlah-N tanah dengan bilangan tangkai m^{-2}, bilangan spikelet $tangkai^{-1}$, dan peratusan spikelet berisi. Analisis komponen prinsipal menunjukkan tiga komponen prinsipal pertama membentuk 59% daripada jumlah variasi dan ianya diwakili oleh status kesuburan tanah, kation gantian di antara Na dan K, dan hubungkait ketumpatan pukal tanah dengan kandungan lempung. Analisis regrasi linar berganda bagi ciri-ciri tanah, kandungan nutrien daun pada peringkat kematangan pokok padi, dan komponen hasil telah memberikan persamaan-persamaan Hasil = 517.78 + 69.13 jumlah N tanah, Hasil = 524.17 – 256.64 N daun + 102085.39 Cu daun + 2663.92 Mn daun, dan Hasil = 1.55 (bilangan tangkai m^{-2}) + 10.20 (bilangan spikelet $tangkai^{-1}$) + 8.05 (peratusan spikelet berisi) – 47.61 (berat biji).

Semivariogram dan kriging berupaya menjelaskan variasi ciri-ciri tanah dan tanaman di sawah padi. Peta variasi bilangan tangkai m^{-2} yang dihasilkan melalui interpolasi kriging didapati mempunyai corak yang menyerupai peta variasi jumlah-N tanah. Sistem maklumat geografi dapat menentukan kedudukkan ruang, dan menghitung keluasan sesuatu julat nilai-nilai angkubah yang ditentukan untuk membantu mengurus sawah padi dengan lebih cekap.

ACKNOWLEDGEMENTS

The author acknowledges with profound appreciation particularly to the Chairman of the Supervisory Committee Dr. Anuar Abdul Rahim for his continuous guidance, encouragement and financial support till the completion of this thesis. To the Supervisory Committee Members Associate Professor Dr. Mohd. Fauzi Ramlan, Associate Professor Dr. Jamal Talib, and Mr. Ismail Adnan Abd. Malek for their valuable guidance and suggestions in the preparation and improvement of this thesis is highly appreciated.

Fullest appreciation is extended to the Land Management Department Laboratory staff members: Mr. Fuzi, Mr. Mokhtar, Mr. Ariffin, Mr. Abdul Aziz, and Mr. Abdul Rahim for assisting him in the soil physical and chemical analyses, Mr. Junaidi Jaafar and Mr. Ghazali, assisted him in taking the study site GPS readings, and Mr. Asri for his willingness in teaching him to use the various useful computer application software programs.

He is grateful to his former staffs of Sungai Burong Rice Seed Production Centre for helping him in collecting the soil and rice plant samples. He is also grateful to Baratlaut Selangor Integrated Agriculture Development Project staff members for their understanding in allowing him to use their office facilities for printing the draft thesis. To his colleague Mr. Syed Fadzil Syed Shahabuddin, Agriculture Officer of the Soil Division, Department of Agriculture who helped in identifying the soil properties to be studied, he extends his thanks. Special gratitude is given to Mr. Bazle Jafri the energetic and dynamic farmer for allowing him to use the rice field as the research site.

Sincere appreciation is extended to the Director General of Department of Agriculture for granting him the study leave and scholarship to pursue his studies. Likewise, the author wishes to express his love and appreciation to his wife and children who provided moral and spiritual support, cooperation and inspiration that led to the completion of this thesis.

Last but by no means least, he expresses his sincere thanks to friends and acquaintances that in one way or another have contributed to the completion of the study.

I certify that an Examination Committee met on 19th December, 2002 to conduct the final examination of Mohd Nasir Warris on his Master of Agricultural Science thesis entitled "Spatial Variability of Soil Factors Affecting Irrigated Lowland Rice Yield" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Agricultural Science. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

(Mohd Nasir Warris)

Date: 25 January 2003

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LIST OF ABBREVATIONS

CN ratio	Soil Total-carbon to Soil Total-nitrogen Ratio
DOA	Department of Agriculture Peninsular Malaysia
GIS	Geographic Information System
GPS	Global Positioning System
MADA	Muda Irrigation Development Authority
LAI	Leaf Area Index
EC	Electrical Conductivity
t ha^{-1}	tonnes per hectare
RSS	Residual Sum of Squares
CV	Coefficient of Variation
PC	Principal Component
PCA	Principal Component Analysis
MARDI	Malaysian Agricultural Research and Development Institute

CHAPTER 1

INTRODUCTION

1.1 Background

Soil spatial variability occurs on a variety of scales, between regions, between fields or within fields (Bouma and Finke, 1993). As soil serves as a growth medium for crops, its physical and chemical conditions affect potential and actual crop yield. Field variability of soil physical and chemical properties revealed spatial crop yield (McBratney and Whelan, 1995).

Physical properties of soil that can vary spatially are structure and texture (McBratney and Whelan, 1995). These two physical properties are important as they influence directly or indirectly on other soil physical properties such as bulk density, water holding capacity and soil strengths. Soil structure affects physical properties such as gas diffusion, water movement and root anchorage. Soil texture influences crop growth and yield by affecting nutrient availability, and water and gas movement (McBratney and Whelan, 1995). Pedogenic processes mainly contribute to the spatial variation of soil texture. Anthropogenic actions such as tillage can lead to changes in soil structure variability (Cattle *et al*., 1994).

Soil chemical properties that vary spatially include nutrients, pH, salinity and organic matter. Spatial variation in nutrients occurred as a results of variation in nutrients uptake by plants, level of leaching or a change to the system such as liming operation altering the chemical balance of the soil (McBratney and Pringle, 1997). Bouma and

Finke (1993) mentioned that fertilizer applications could increase the spatial variability of soil nutrients due to uneven spreading patterns. Soil pH and salinity vary spatially depending on factors that affect its accumulation and decay such as temperature, pH, moisture content, oxygen availability, soil texture and management practices (Jenkinson, 1988).

Current standard methods of soil sampling are designed to obtain a representative composite sample from an area that is considered to be uniform with respect to soil types, previous cropping, and fertilizer and lime use. In practice, a single field is normally considered the sample area, although some large fields may be divided into more than one sample (Dampney, 1997). Recommendations such as a uniform fertilizer rate and seeding rate are made for the entire field without considering short ranged field variation.

Precision agriculture is an approach for sub-dividing the fields into small, relatively homogeneous management zone where agronomic practices such as tillage, liming, seeding, fertilizing, herbicide spraying and infield water management are custom managed according to the unique mean characteristics of the management zone (Mulla, 1997). Precision agriculture is a site specific management which will only be relevant if agronomists have precise information on spatial soil conditions to enable delivering of accurate specific advise (Voltz, 1997).

In Malaysia, there is a need for adoption of precision agriculture in the research and extension of rice crop. New available technologies such as geostatistics, Geographic Information System (GIS), Global Positioning System (GPS) and remote sensing can be utilized to assist in the implementations of precision agriculture in rice farming (Laili, 2000). At present, it is necessary to gather data to characterize the small-scale soil variability factors that may be expected over space and time in a rice field. Research is required to ensure the data collected is representative of the true variation at this small scale, to provide insights into its implications and use, and to maximize the benefits obtained for agricultural farm management.

A field experiment was undertaken to test the hypothesis that spatial variability of soil factors exist in a rice farm. In testing this hypothesis, the following aspects were investigated:

1. The spatial variability of soil factors, rice leaf nutrient content, yield, and yield components.
2. Correlations between soil factors with leaf nutrient content, soil factors with yield and yield components, and leaf nutrient content with yield and yield components .
3. Soil factors affecting yield and yield components of rice.

1.2 Objective of the Study

The objectives of this study are

1. To determine the spatial variability of soil factors of a rice farm.
2. To correlate soil nutrient with rice leaf nutrient content.
3. To determine the soil factors affecting yield and yield components.

CHAPTER 2

LITERATURE REVIEW

2.1 Rice Industry

Although rice is cultivated as far as 49 °N in Czechoslovakia (Kratochvil, 1956) and as far south as 35° in Australia but more than 90% of the world's rice growing-area is in Asia. These include countries in the South Asia region like India, Pakistan, Bangladesh, Nepal and Sri Lanka and countries in the Southeast Asia region like Myanmar, Cambodia, Laos, Vietnam, Thailand, Malaysia, Indonesia and Philippines. Countries in the East Asia region like China, Japan, Taiwan and Korea is another important rice-growing region of the world. World acreage of cultivated rice in 1998 was about 150.30 million hectare and rice crop ranks second to wheat in terms of harvested area. The world rice production in the year 1998 was around 563.20 million tonnes with average yield of 3.75 t ha^{-1} (Anon, 2000).

Rice is an important food crop in Malaysia and forms the staple diet of the Malaysians. Having average annual cropped area of about 660,000 ha in terms of total harvested area of main season and off season planting in 1998, rice is the third most important crop in Malaysia in terms of land-use after oil palm and rubber with 2.89 and 1.57 million ha respectively (Anon, 1999). The country average farm size estimated at 1.50 ha with only two percent of farms exceeding 3.00 ha. The number of households engaged in rice farming as a major income were 116,000 and higher number of households involved in rice farming as a minor income of 200,000 households (Jegathesan, 1996).

In 1998, Malaysia produced 2.13 million tonnes of rice and met 73% of the country self-sufficiency level (Anon, 1999). The national average for rough rice yield in the main planting season 1999/2000 was 3.57 t ha^{-1} with Peninsular Malaysia achieving yield of 3.56 t ha^{-1} compared to 3.78 t ha^{-1} for Sabah and 1.63 t ha^{-1} for Sarawak. The national rough rice yield average can be considered low when compared to rough rice yield obtained from the well irrigated and better managed rice granary areas such as the Barat Laut Selangor Integrated Agricultural Development Project with average yield of 4.57 t ha^{-1} and MADA with average yield of 3.92 t ha^{-1} during the main planting season 1999/2000. In Barat Laut Selangor Integrated Agricultural Development Project more than 12.50 % of the rice area had achieved greater than 6.00 t ha^{-1} of rough rice yield (Anon, 2001).

The rice-growing areas of Peninsular Malaysia can be divided into three main types of physiographic regions. Firstly, the marine coastal plain commonly found on the west coast has a fertile rice field such as the Muda Irrigation Scheme and the Barat Laut Selangor Integrated Agricultural Development Project but there are also swampy parts of the coastal plain facing problems of excessive saturation, salinity and organic matter accumulation encountered as in the Krian Laut Irrigation Scheme. Secondly, the riverine flood plain found mainly on the east coast such as Kemubu and Besut Irrigation Schemes may have colluvial, deposits from nearby hills and most of the soils in this region are stratified. Thirdly, the inland valleys found mainly in the middle and upper reaches of major and minor rivers such as in Negeri Sembilan, Melaka, Johor and Pahang (Samy *et al*., 1980). The soils on the marine sediments have a higher pH, higher organic matter content, higher cation exchange capacity and better plow sole development than those soils developed on riverine alluvia. The mineralogy of the soils